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SPECIAL NONDESTRUCTIVE TECHNIQUES

FOR EVALUATING

SPACE SHUTTLE SURFACE INSULATION

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INTRODUCTION

Advanced materials systems generally require improved, unique and advanced nondestructive testing techniques.

These techniques often become the pacing or limiting item for the utilization of new material systems. Some agencies, such as the Nuclear Reactor Branch of the Bureau of Ships, do not permit new designs to be used in critical structures and components if they cannot be adequately inspected by NDT techniques.

The Space Shuttle vehicle will use new and advanced material systems and will require sensitive NDT techniques for assuring the initial quality of the materials and structures. In addition, this multi-use re-entry vehicle will have to be nondestructively evaluated periodically to assures its reuse capability.

At General Electric-Reentry and Environmental Systems Divisions, we are developing sensitive NDT techniques as we develope the thermal protection system materials. Primarily these materials consist of fibrous composites of mullite with a protective coating and appropriate attachment systems.

NDT techniques have been developed for performing in-process evaluations for material variability and for process control. Several of these techniques show considerable promise for evaluating the reusable surface insulation during the operational phase of the shuttle.

DISCUSSION OF NDT TECHNIQUES

A. Radiographic Densitometry

The mechanical and thermal properties of the mullite composite are greatly influenced by the variability in local density and it is therefore necessary to measure the variability and to control it during processing steps.

This is done, at GE-RESD, by obtaining an image of a step block of mullite composite, with known density steps on each x-ray of the billet. (Figure 1).

The x-ray film is then scanned with a photodensitometer and variations in photometric density are calibrated with the known density gradients of the x-ray image of the step block. The areas of greatest variability are recorded, as well as the average. This information is plotted and maintained on a Quality Control Chart to monitor the process variability and to assure that the process remains in control.

In addition, the density data from each billet is used for predicting the mechanical properties by means of the sonic modulus equation:

$$V_1^2 d = E_D \quad \text{where}$$

V_1 = longitudinal sonic velocity

d = density

E_D = dynamic modulus

B. Sonic Velocity and Sonic Modulus

The sonic velocity of a material is a fundamental physical property and is related to the mechanical properties of stress and strain. In composites,

the velocity can often be empirically correlated with modulus and is useful in predicting and monitoring the directional mechanical properties. In materials having a very low strain value, the sonic velocity may permit good approximations to be made on the ultimate tensile properties.

The sonic velocity is obtained by means of a system shown schematically in Figure 2. The velocity is measured through the thickness of the billet in the same locations as we obtained the radiometric density reading. The velocity measurement, thus obtained, is used in the modulus equation to monitor the variability of this mechanical property (Figure 3). This measurement is also plotted graphically on a control chart as a means of monitoring the process variability.

C. Infrared Coating Evaluation

The external insulation material is covered by a ceramic coating to make it waterproof and also to give a proper emissivity and erosion resistance.

Small defects in the coating, which may result from processing variables or damage from handling and environmental cycling, are detected by a unique application of an infrared test.

In this test, the specimen or assembly is covered with a film of water which is applied by brushing or dipping. The water is wiped away from the surface after a few minutes and the part is warmed slightly by means of a heater unit.

When the specimen is viewed with the infrared scanning camera the damaged or defective areas stand-out markedly as dark regions on a light background (See Figure 4).

The water penetrates through pinholes or cracks and then spreads into the mullite material in the immediate vicinity of the defect. The zone which is formed is considerably larger than the defect and, as a result, is easily detectable. The whole process is similar to a standard dye penetrant technique but does not contaminate the material and serves as a truly functional test.

In addition to the waterproofness test, the infrared technique is sensitive to non-adhering coating areas. These areas also show up as darker (cooler) areas and can be seen by slightly warming the specimen and viewing it with infrared scanner as it cools.

D. Beta-Backscatter Coating Thickness

The coating thickness is a parameter which must be monitored to assure multi-mission erosion resistance.

At General Electric-RESD, we use a Betascope backscatter method which can readily measure discrete coating areas to a precision of about ±.001".

In this technique, a beta emitting isotope is placed in proximity to the coated surface and the beta energy backscattered onto a detector cell is measured over a 15 second interval. The integrated beta energy is directly proportional to the coating thickness (Figures 5, 6).

SUMMARY

In summary, several unique and sensitive NDT techniques have been successfully applied to the GE-RESD external insulation materials for in-process monitoring and control.

Some of these techniques can be applied to large structures or are portable enough to be used for evaluating the material when it has been installed on the Space Shuttle vehicle. The infrared technique will be further investigated for evaluating the operational vehicle for coating defects and damage and the beta-backscatter may be applied to the operational vehicle to measure residual coating thickness.

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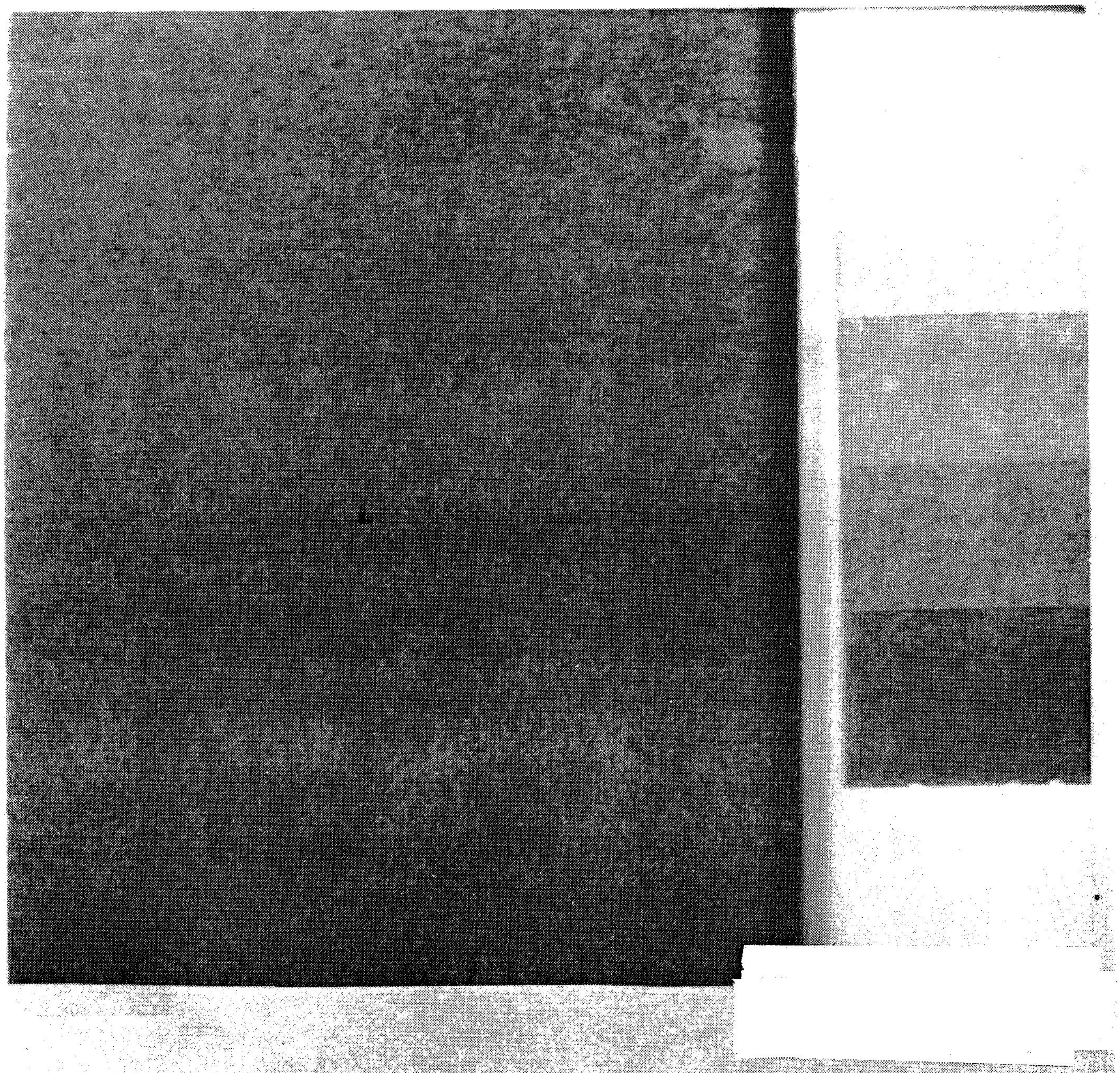

FIGURE 1 - X-RAY REVERSAL PRINT OF REUSABLE SURFACE INSULATION PANEL SHOWING THE VARIABLE DENSITY STEP BLOCK.

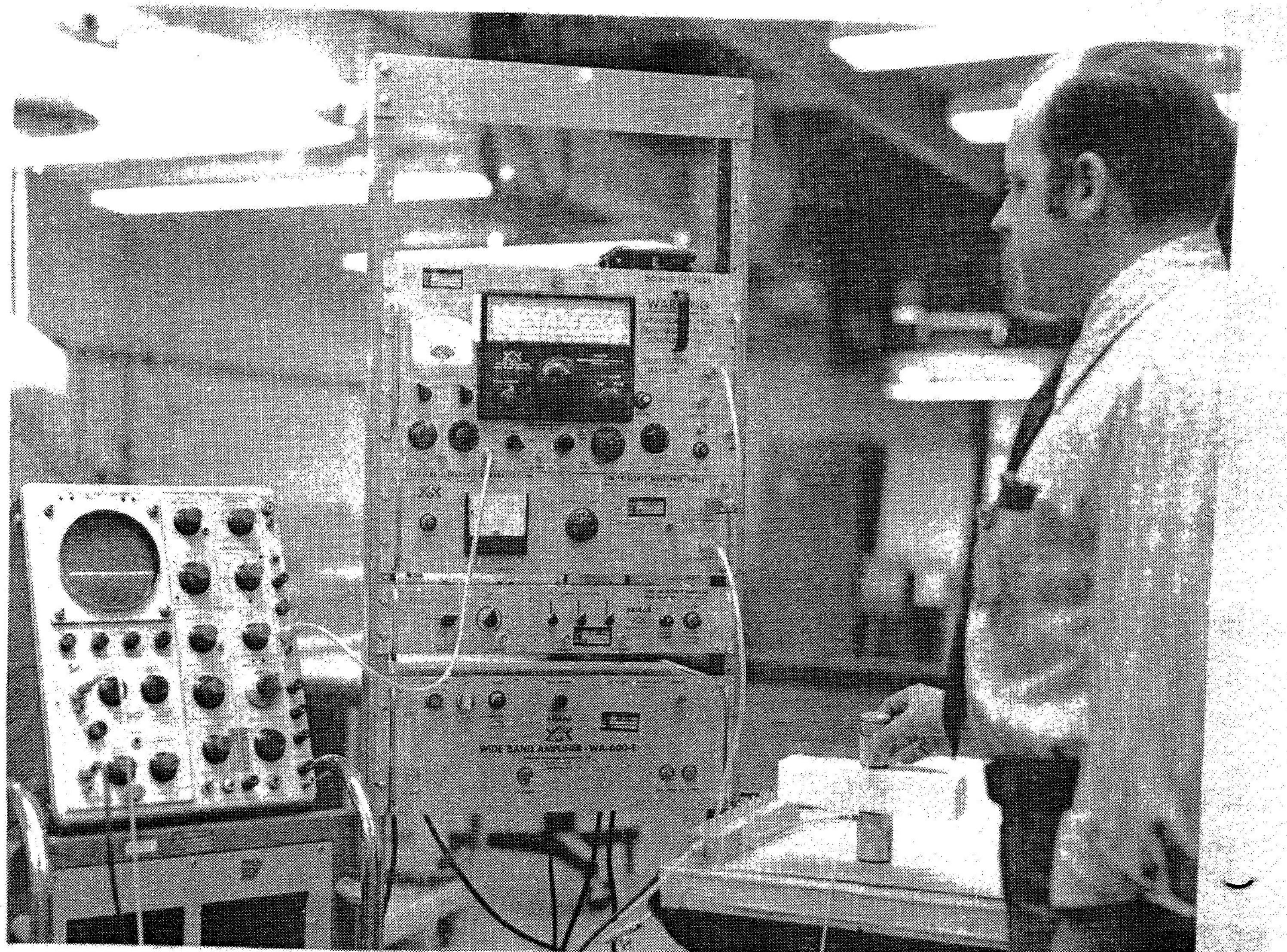

FIGURE 2 – SONIC VELOCITY AND MODULUS MEASUREMENT EQUIPMENT.

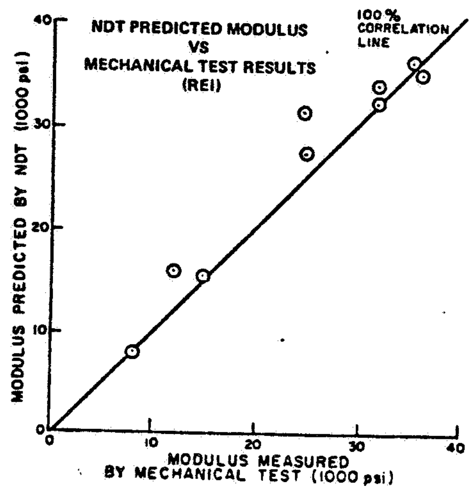

FIGURE 3 - CORRELATION OF NDT MEASURED SONIC MODULUS AND TENSILE MODULUS OF REUSABLE EXTERNAL INSULATION

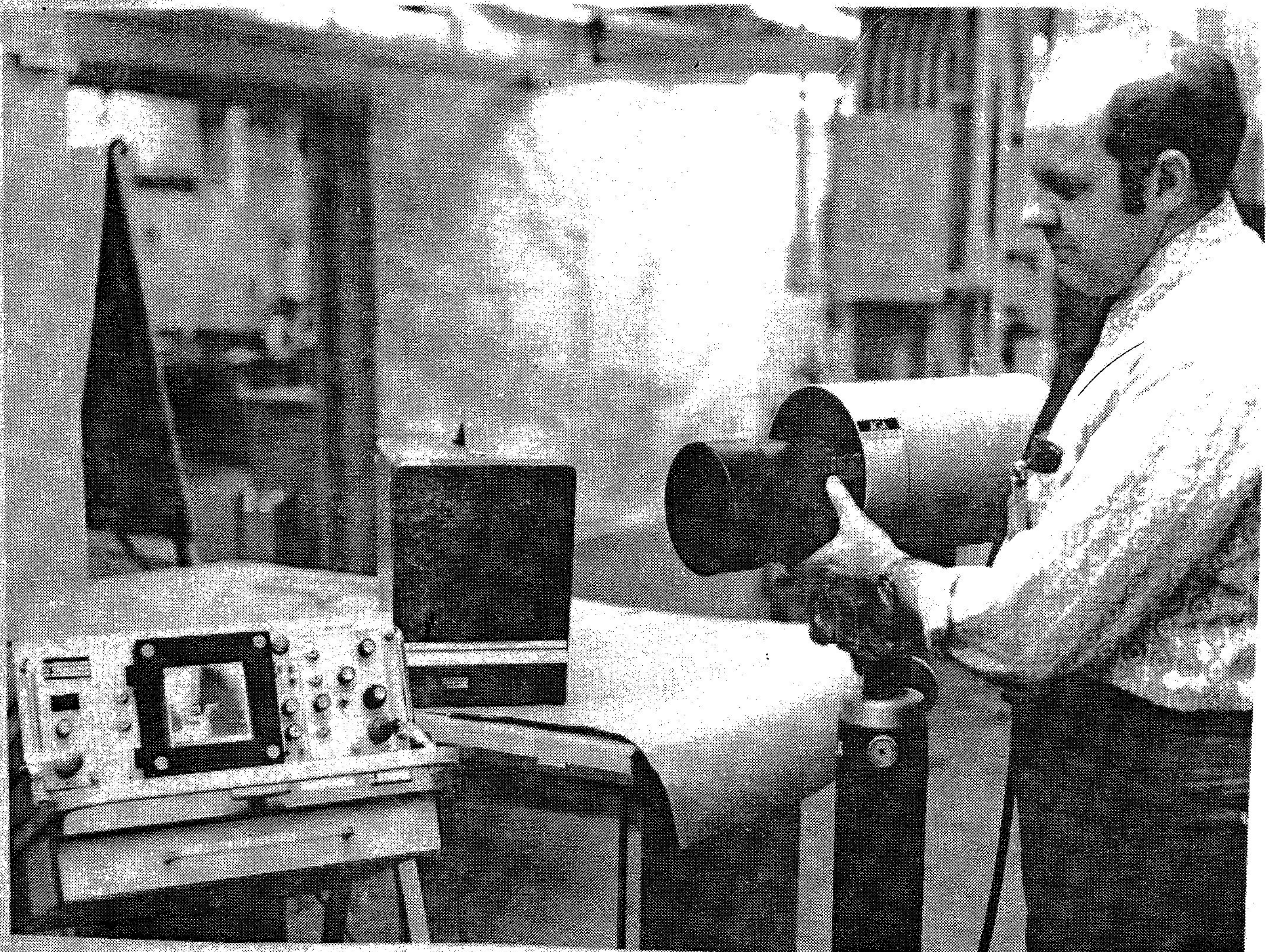

FIGURE 4 - G. E. INFRARED SCANNING CAMERA SYSTEM FOR EVALUATING REUSABLE EXTERNAL INSULATION FOR WATERPROOFNESS

FIGURE 5 - BETA-BACKSCATTER METHOD FOR MEASURING COATING THICKNESS ON REUSABLE EXTERNAL INSULATION.

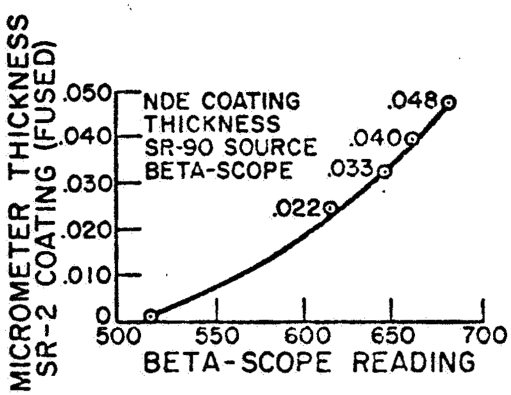

FIGURE 6 - CORRELATION OF BETA-BACKSCATTER MEASUREMENT AND ACTUAL COATING THICKNESS ON REUSABLE EXTERNAL INSULATION